Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Faculty of Engineering, Mathematics and Science

School of Computer Science & Statistics

MSc Computer Science **Semester 1 2022**

Year 1 Annual Examinations

CS7NS3 NEXT GENERATION NETWORKS

12th December 2022 **RDS-SIM COURT** **09:30–11:30**

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Instructions to Candidates:
Answer ONLY TWO questions from Part A, ONLY TWO questions from part B, ALL questions from part C.

Materials permitted for this examination:
This is a closed book examination. Materials Permitted: Calculator.

PART A [36 marks] - ONLY answer 2 questions

Q.1 **[Total: 18 marks]**

(a) Assume we have a CDMA system and that a 1 is transmitted as a positive pulse +L and a 0 is transmitted as a negative pulse -L. A certain station A is assigned the code 110100 and another station B can choose among the codes 111000, 100001, and 000111, respectively. Which code should B use and why?

[6 marks]

(b) Suppose that A and B both want to send a 1 simultaneously. What is decoded at the receiver for A and B transmissions? Outline in detail the decoding procedure.

[6 marks]

(c) Suppose that simultaneously *A* wants to send a 1 and *B* wants to send a 0. What is decoded at the receiver for *A* and *B* transmissions? Outline in detail the decoding procedure.

[6 marks]

Q.2 **[Total: 18 marks]**

(a) In a single server system, arrivals can be modelled as a Poisson process with rate of 3 min^{-1} and the service times are exponentially distributed with mean 15 s.

- Give the Kendall's notation, justifying your choice.

[2.5 marks]

- Calculate the average number of customers in the system.

[1.5 marks]

- Calculate the average delay and the average waiting time.

[1.5 marks]

- Calculate the average number of customers in the queue.

[1.5 marks]

- What happens to the average number of customers in the system, if service times are exponentially distributed with mean 20 s? Why?

[2 marks]

(b) In a certain system the arrivals, which can be modelled as a Poisson process, occur at a rate of one every 100 ms, and the service times are exponentially distributed with mean 2 s. Also, there is no limit in the number of servers available.

- Give the Kendall's notation, justifying your choice.

[3 marks]

- Calculate the average number of customers in the system.

[3 marks]

- Calculate the average delay per customer.

[1.5 marks]

- Calculate the average queuing delay. What do you notice? Why it is so?

[1.5 marks]

Q.3 **[Total: 18 marks]**

In the following equation:

$$C = m \cdot B \log_2 \left(1 + \frac{S}{N}\right) \qquad (1)$$

C represents the channel capacity [bps], B the system bandwidth [Hz], S the useful signal power [W], N the noise power [W], and $m = R_s \cdot O_m \cdot R_c$, where R_s is the multiple antenna spatial rate, O_m is the modulation order [bits / modulated symbol], and R_c is the channel coding rate. Assume that $\frac{S}{N} = 1$.

(a) Assume the following system components are available:

- Multiple antenna schemes: spatial diversity-only mode with a spatial rate of 1, hybrid diversity-spatial multiplexing mode with a spatial rate of 2, spatial multiplexing-only mode with a spatial rate of 4;
- Modulation schemes: QPSK, 16-QAM, 64-QAM;
- Channel coding rates: 1/3, 1/2, 2/3;
- Bandwidth: 100 MHz, 200 MHz, 500 MHz.

One wants to achieve a throughput equal to 2 Gbps or higher. Outline two systems obtaining that by using the above-mentioned system components.

[5 marks]

(b) Considering equation (1) above, now suppose that an adaptive system can switch among the configurations A, B and C, where:

- A = {spatial rate = 1, QPSK modulation, channel coding rate = 1/3, 100 MHz bandwidth}, if Signal-to-Noise Ratio (SNR) is below 0 dB;
- B = {spatial rate = 2, 16-QAM modulation, channel coding rate = 1/2, 200 MHz bandwidth}, if the SNR is greater or equal than 0 dB and below 10 dB;
- C = {spatial rate = 4, 64-QAM modulation, channel coding rate = 2/3, 500 MHz bandwidth}, if the SNR is greater or equal than 10 dB.

Assuming that the probability distribution for the three SNR regions is uniform, calculate the average capacity of the adaptive system.

[7 marks]

(c) In case you want to provide better coverage to mobile users far away from the base station, what values (choosing between 'high' and 'low') of coding rate, modulation order and multiple antenna spatial rate should you choose (justify your answer)? What will be the impact of the above choice on the system's spectral efficiency?

[6 marks]

PART B [36 marks] - ONLY answer 2 questions

Q.4 **[Total: 18 marks]**

(a) Considering an optical transmission system, describe how an eye diagram is generated and what information it can provide. Then draw an example of an eye diagram for a ON-OFF Key modulation transmission with large amount of noise and one for a PAM4 (Pulse Amplitude Modulation with 4 levels) modulation with small amount of noise.

[9 marks]

(b) Describe what are Optical Signal to Noise Ratio (OSNR) margins in optical networks and why are they used. Then describe the pros and cons of using more conservative versus more aggressive margins.

[9 marks]

Q.5 **[Total: 18 marks]**

Provide a solution, using any appropriate quality of service (QoS) tool, for the following two QoS problems:

(a) You need to process three traffic flows:

- Flow 1 should have a Committed Information Rate (CIR) of 3 Gb/s and Peak Information Rate (PIR) of 5 Gb/s. Flow 2 a CIR of 5Gb/s and PIR of 8 Gb/s and Flow 3 has only a PIR of 2Gb/s.
- The scheduler applies relative priority to all flows and classes:
    i. CIR packets are served at a rate 4 times higher than PIR packets.
    ii. Flow 1 and Flow 2 are served at the same relative rate; while Flow 3 is served at half their rate. This rule is valid for CIR and PIR packets, although rule (i) above also needs to be implemented.
- All Flows exit through the same physical interface of 10Gb/s capacity.
- Show, using appropriate detailed diagrams and explanations, how you would put together a chain of different QoS tools to implement your solution. Provide detailed information of any parameters (including weights, expressed in percentage for the schedulers), required for any of the QoS tools.

[9 marks]

(b) You need to process two traffic flows:

- Flow 1 has 6 Gb/s of CIR and 9Gb/s of PIR. Flow 2 has 7Gb/s of CIR and 10Gb/s of PIR.
- The scheduler should give absolute priority to CIR packets compared to PIR packets. CIR packets from Flow 2 are served at three times the rate than Flow 1. The same rate applies to the PIR packets of the two flows.
- Considering that physical interfaces can work at the rate of 1 Gb/s or 10Gb/s, select the minimum number of interfaces required to meet the minimum QoS requirement of the system.
- Show, using appropriate detailed diagrams and explanations, how you would put together a chain of different QoS tools to implement your solution. Provide detailed information of any parameters (including weights, expressed in percentage for the schedulers), required for any of the QoS tools. **[9 marks]**

Q.6 **[Total: 18 marks]**

A Wavelength Division Multiplexing (WDM) transmission system with 40 channels needs to operate over a 1,000 km distance. Amplifiers have 15 dBm of power and noise figure of 6 dB, while the fibre has a nominal attenuation of 0.2 dB/km. The distance between amplifiers is 50 km. The signals all transmit at 33 Gbaud (occupying a 37GHz bandwidth). Also consider that a margin of at least 4 dB is required.

(a) What is the maximum useful data rate of your system, considering all channels, if the required OSNR for 16QAM, 32 QAM and 64 QAM modulations are, respectively, of 18, 23 and 28 dB? Notice that these rates can only be achieved using error correction codes, which have an overhead of 9% (i.e., they use 9% of the channel capacity).

[10 Marks]

(b) What is the chromatic dispersion of each channel if the average dispersion coefficient of the fibre is 17 ps/nm/km (assume the following conversion ratio: 100 GHz = 0.8 nm)? If the transmissions were carried out using direct detection receivers and the transmitters worked at the same Baud rate described above (i.e., 33Gbaud), how much dispersion compensating fibre (DCF) would be required at each amplifier location to compensate for dispersion? Assume the DCF has coefficient of -150 ps/km/nm.

[8 Marks]

PART C [28 marks]

For each question you pick, select only ONE answer out of the four available options. Answer ALL questions.

Q.7

Which one among the following functionalities does **not** belong to the OSI Physical (PHY) layer?

a) Frame synchronization
b) Waveform selection
c) Signal detection
d) Power control

[3.5 marks]

Q.8

Which one among the following options, would likely be **most** suitable to comply with the requirements of enhanced Mobile Broadband systems?

a) Spatial multiplexing & coding rate of 1/3
b) Spatial diversity & coding rate of 1/3
c) Spatial multiplexing & coding rate of 2/3
d) Spatial diversity & coding rate of 2/3

[3.5 marks]

Q.9

Which one among the statements about schedulers is **incorrect**?

a) Proportional Fair is the de-facto choice in modern cellular networks
b) Maximum C/I is well suited for high throughput services
c) Proportional fair is not in use in Wi-Fi systems
d) The scheduling used by Wi-Fi is based upon the same principle as the scheduling used by cellular systems

[3.5 marks]

Q.10

Which of the following options is **helpful** in increasing a link reliability?

- **a)** Using a higher order modulation
- **b)** Using a lower coding rate
- **c)** Increasing the spatial multiplexing gain
- **d)** None of the above

[3.5 marks]

Q.11

Why is Dispersion Compensating Fibre only required for intensity modulated direct detection systems?

- **a)** Because coherent systems do not suffer from inter symbol interference
- **b)** Because coherent systems make use of higher order modulations that do not suffer from dispersion
- **c)** Because intensity modulated systems tend to transmit at higher baud rate, since they use lower order modulations.
- **d)** Because coherent system can make use of the additional phase information of the signal to compensate for dispersion digitally

[3.5 marks]

Q.12

What is the difference between color blind and color aware two rate three color marking (TrTCM)?

- **a)** In color aware mode, yellow packets cannot enter the green queue
- **b)** In color blind mode, yellow packets cannot enter the green queue
- **c)** In color aware mode, green packets cannot be moved to the yellow queue
- **d)** In color blind mode, green packets cannot be moved to the yellow queue

[3.5 marks]

Q.13

Why in a Radio Access Network (RAN) with functional split, splits D and E have lower latency requirements than other splits?

a) Because they both send I/Q samples to the antenna site, which needs to be processed with low delay and jitter.

b) Because they transmit at higher data rates, which then requires compression, which introduces additional delay.

c) Because the Hybrid Automatic Repeat Request (HARQ) function is located above the split D.

d) Because they scale with the number of Multiple Input Multiple Output (MIMO) ports, which require strict synchronisation.

[3.5 marks]

Q.14

Which of the following is **not** a reason why broadband based on fibre is better than broadband based on copper?

a) Because the speed of light in fibre is higher than the speed of an electric current in copper

b) Because fibre has higher transmission bandwidth

c) Because fibre has higher signal to noise ratio

d) Because fibre has lower transmission loss

[3.5 marks]